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THE IMPORTANCE OF SHORAN SURVEYING IN THE SOUTHERN HEMISPHERE

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THE IMPORTANCE OF SHORAN SURVEYING IN THE SOUTHERN HEMISPHERE

Carl I. Aslakson

Within the span of the last decade, the surveying and mapping engineer has begun to acquire a strange new vocabulary. In speaking of surveying instruments, we hear such names as Shoran, Raydist, Decca, Irrad, Moran, Geodimeter and Electronic Position Indicator. This is only a partial list. The surveyor also speaks glibly of radio altimetry, profile recorders, the refractometer, dielectric constant of the air, velocity of radio waves and similar subjects. This has been brought about by the rapid development of electronic surveying, a new method of surveying which already is having a profound effect on the future of surveying and mapping.

Geodetic control on a unified continental datum is being established throughout the island areas of the Antilles. Control is being established in vast areas of the Canadian wilderness. Other important geodetic ties are being made throughout the world.

An attempt to give a detailed account of any one of these new instruments and its method of use would fill a large volume. Many papers have been published and for the benefit of those who would inquire further, a brief bibliography on electronic surveying and related subjects is included in this paper. In the present paper, I shall restrict my discussion to a single instrument and its use. That instrument is shoran, a World War II blind-bombing instrument, which has been modified and adapted to surveying. This course was chosen for two reasons; first, because of my greater familiarity with shoran, and second because it is in more extensive practical use at this time than any other system. In restricting this paper to shoran, I do not wish to imply that similar instruments cannot be used to accomplish the same purpose after they have undergone extensive trials. I further believe that long distance trilateration by shoran combined with shoran-controlled photography is of greater importance to South America, Mexico, Central America and the Antilles, than electronic surveying instruments designed to compete with the conventional type. This is true because shoran will span the oceans for great distances, map difficult and even inaccessible terrain and enable all these maps to be placed on a single datum.

What is Shoran?

What is shoran? For more detailed reports on shoran design and operations, reference is made to the previously mentioned bibliography. In this paper only the barest essentials can be covered. Shoran is a transceiver-transponder system by means of which radio wave travel time is accurately measured from an airplane to each of two antennas at ground stations. This time measurement is directly translated into distance which is read on dials or automatically recorded. These air-ground distances can then be reduced to geodetic distances by the application of corrections which involve certain instrumental corrections, meteorological factors, and the altitudes of the aircraft and ground stations.

Test of Shoran Accuracy

Reports on the shoran tests have been published from time to time, but only the results from the last and most extensive test will be presented herein. (See Figure 1.) This test was carried out in Florida during 1950 where a total of 15 distances were measured by shoran and the results were compared with the distance obtained from conventional first order triangulation. The distances varied in length from forty miles to three hundred twenty miles. In Table I the results of this test are listed. The maximum discrepancy with a surveyed distance was about one part in 40,000. The average discrepancy was .0012 mile or approximately six feet.

One of the most convincing results of this project was the discovery of a local surveying error (See Reference 10) at Key West, Florida. In that instance, five shoran measurements were made to this station from other shoran stations, the shortest measurement being about 96 miles and the longest 320 miles. On the basis of a computation using the shoran measured distances, it was predicted that a local surveying error of 35.4 feet in azimuth 39-3/4 degrees was present. Several months later, triangulation by the U. S. Coast and Geodetic Survey revealed that the error actually was 36.4 feet in azimuth 37°.

A second convincing proof of shoran accuracy lies in the fact that measurements made by this method (See Ref. 17, 18, 21, 24 and 27) have been accepted by physicists throughout the world as a new and accurate determination of c or the velocity of light. Almost from the outset, during shoran research, strong indications were found that the Birge statistical value of c or 299,776 km per second was too low. The writer finally published two new values of 299,792.4 and 299,794.2 km per second, based on shoran measurements in Florida. A tabulation of other recent measurements follows:

AUTHOR	DATE OF PUBLICATION	METHOD	VELOCITY km/sec
Aslakson	1949	Shoran	299,792.4 $\pm$2.4
Hanson and Bol	1950	Cavity Resonator	299,789.3 $\pm$1.2
Essen	1950	Cavity Resonator	299,792.5 $\pm$4.5
Aslakson	1950	Shoran	299,794.2 $\pm$1.4
Bergstrand	1951	Geodimeter	299,793.1 $\pm$0.3
Froome	1952	Microwave Interferometer	299,792.6 $\pm$0.7
DuMond and Cohen	1952	* Statistical	299,792.9 $\pm$0.8

* Based on a least squares adjustment of atomic constants.

Clearly, both shoran measurements approach very closely to the statistical value of DuMond and Cohen.

What Shoran Can Accomplish

The advantages of this method of electronic surveying can be enumerated.

1. Geodetic accuracy can be obtained over distances as great as 500 miles.
2. Errors are a function of time and therefore do not increase with distance.
3. Aerial photography can be controlled by shoran distances, permitting accurate mapping of all areas within the range of the shoran ground stations.

4. Navigational devices utilizing the shoran distance readings, permit flight line navigation of great accuracy.

5. Shoran photographic techniques permit the establishment of control points of lower accuracy without setting foot on the ground.

6. Vertical control of various degrees of accuracy are possible by shoran-photographic-radio-altimeter methods.

Each of the above features of shoran will be elaborated upon.

Shoran Geodetic Surveying

The survey of the Air Force Missile Test Center Range from Florida to Puerto Rico is an excellent example of the use of shoran. (See Figure 2.) Without these new techniques, all of the islands now being surveyed would be doomed to remain geodetically isolated. Now, by means of shoran, the Bahama Islands, Cuba, Hispaniola, and Puerto Rico will all have a unified datum. The distance measurements are accomplished by flying across the line joining two ground stations and making an analytical computation of the minimum sum distance which is then reduced by the corrective terms to the geodetic distances. (See Figures 3 and 4.)

An important feature of shoran geodetic control is that in general the schemes can be so situated as to span mountain ranges or jungle areas. The ground stations may be situated in plains areas or on accessible rivers where the logistics problems are reduced to a minimum. The aircraft measurements may then be made above the mountains or jungle which might be completely inaccessible to conventional surveying parties.

Electronic Measurement As Timing Measurement

Let us consider another important aspect of electronics measurements; in conventional surveying, an erroneous tape length produces an error directly proportional to distance. In an electronic measurement, the unit measured is time and our timing device is a controlled crystal frequency. With modern methods, crystal frequency can easily be accurate to better than one part in 1,000,000. Thus, long distances of hundreds of miles can be measured with nearly the same accuracy as distances of twenty-five to fifty miles.

Shoran Controlled Photography

Extensive use is being made of shoran controlled photography by the United States and Canada. (See Figure 5.) The principle of shoran photogrammetry is simple. Two distances to each of two shoran stations are recorded simultaneously with the exposure of the picture. Several methods of photographic analysis have been developed to utilize these distances in controlling the map-compilation. The conclusion has been reached that 1:500,000 maps can be produced in this manner without other horizontal ground control. The efficiency of a combined shoran geodetic-photogrammetric operation is therefore obvious. Geodetic measurements can be made under conditions which prevent photography such as in darkness or fog, or when there is extensive cloud coverage. Therefore the higher priority can be allotted to photography and the combined operation can operate very efficiently utilizing the non-photographic weather to measure the distances for geodetic control.

Flight Line Navigation

At least four different flight-line navigators have been developed in the United States, Canada, and Australia which utilize the shoran distance measurements to control the aircraft navigation. These instruments are simple in principle and highly successful. They enable the airplane to be navigated so accurately over unmapped terrain that gaps between adjacent flight lines are almost non-existent. This makes shoran flight-line navigation most economical, for side-lap can be kept to a minimum.

Secondary Photographic Control

The main scheme trilateration furnishes the first order control. The shoran-controlled photography may be considered as third order. If, then, it is desired to establish other points of a somewhat intermediate accuracy or, let us say, a second order control, this operation can be performed by a shoran-photographic method.

In Figure 6, we see an example of this. It is desired to locate two islands on which no main scheme shoran station is placed. Repeated flights in four directions as shown in the figure, with the camera operating at minimum exposure interval and with simultaneous pairs of shoran distances recorded for each picture, will furnish the data necessary to obtain the ground coordinates of a selected point, using any one of several methods of photogrammetric analysis. This procedure has been tested in the United States and in Canada and was used extensively in the Florida-Puerto Rico survey. The conclusion is that a ground point may be positioned with an accuracy of from $\pm$100 feet down to $\pm$25 feet relative to the two shoran stations used. The degree of accuracy is dependent on the method of analysis and whether or not any local horizontal control exists in the area photographed. The important feature of this technique is that a geodetic position can be obtained in this manner in an inaccessible area without setting foot on the ground.

Vertical Control

Radio altimetry has not kept pace with horizontal control developments, but some degree of success has been attained. The Canadians have claimed a relative accuracy of $\pm$10 feet for a Canadian developed profile recorder. Certain narrow beam radio altimeters are developed in the United States but their possibilities have not been completely explored. The British have made tests with an instrument similar to shoran, and with one of their radio altimeters in which it was concluded that an accuracy of $\pm$10 meters was possible.

One technique which is promising has been tested by Australia, Canada, and the United States. This process consists of the establishment of datum planes as shown in Figure 7.

If an airplane flies along a constant pressure level at a sufficient height so that the winds are geostrophic, that is, these winds are caused solely by the rotation of the earth, the differential height between the constant pressure surface and a level surface can be computed from certain readily observable data when shoran navigation is used. This height difference is shown as ΔH in Figure 7. The expression for H is a simple one:

$$H = \frac{VS \sin\alpha \sin\phi}{K}$$

where ΔH is the change along the constant pressure level; V is the wind velocity; α is the angle between the aircraft heading and the wind; ϕ is the mean latitude of the line; S is the air distance along the flight line; and K is a constant depending on the units used. Thus, datum planes, as for example the lake surface shown in the figure, can be tied by radio altimetry to a known elevation such as sea level. A large number of these datum surfaces, locked together by cross ties, can be adjusted into a single scheme of elevations. These surfaces can then be bridged by photogrammetric methods. The Australians claim an accuracy of approximately ± 10 meters for a single observation. At the present time this figure should be considerably improved and the adjusted datums should be still further improved.

Conclusions

The applications of this new mapping method have been described. Vast areas exist throughout the equatorial belt and in the southern hemisphere, where only navigational charts exist and many of them are of questionable accuracy. No unified datums are in existence. We have, in this new method of mapping, a means by which large scale maps can be rapidly produced, and these maps can all be compiled on a single datum. Consider a specific case, the establishment of a South American datum. A complete network of shoran trilateration can be established covering the entire continent. This network would be tied in to existing arcs of triangulation. These ties serve a dual purpose. First, they scale the shoran scheme and thus obviate any necessity of an exact knowledge of the velocity of propagation of radio waves. Secondly, they are controlled by LaPlace azimuths and thus serve to control the shoran network in azimuth. Now, if astronomic positions are observed at all shoran stations, a least square solution will determine a datum which will be the best fit for the entire continent. The practical and scientific value of such a project can hardly be overestimated.

A project such as outlined above would require cooperation of all the South American governments and their surveying agencies. If this cooperation were secured, the individual cost to each nation would not be excessive. With efficient preparation the entire project could be consummated in from one to three years.

History has proved that development follows good mapping. The small financial outlay required for this project would return its initial cost many times over in increased development of the natural resources of cooperating nations.

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LINE	GEODETIC DISTANCE IN MILES	ADJUSTED SHORAN DISTANCE (MILES)	GEODETIC MINUS SHORAN (MILES)	PROPORTIONAL DISCREPANCY (PARTS IN 10^6)
1	40.6131	40.6123	+.0008	19.7
2	96.7171	96.7147	+.0024	24.8
3	100.3098	100.3105	-.0007	7.0
4	118.9953	118.9951	+.0002	1.7
5	133.0113	133.0122	-.0009	6.8
6	134.9698	134.9685	+.0013	9.6
7	139.1225	139.1250	-.0025	18.0
8	145.8427	145.8420	+.0007	4.8
9	145.8884	145.8913	-.0029	19.9
10	190.5047	190.5060	-.0013	6.8
11	199.1914	199.1912	+.0002	1.0
12	226.9903	226.9893	+.0010	4.4
13	235.5264	235.5241	+.0023	9.8
14	277.0569	277.0572	-.0003	1.1
15	320.1519	320.1521	-.0002	0.6
		MEANS	.00118	9.1

TABLE I - SHORAN RESULTS IN FLORIDA TEST

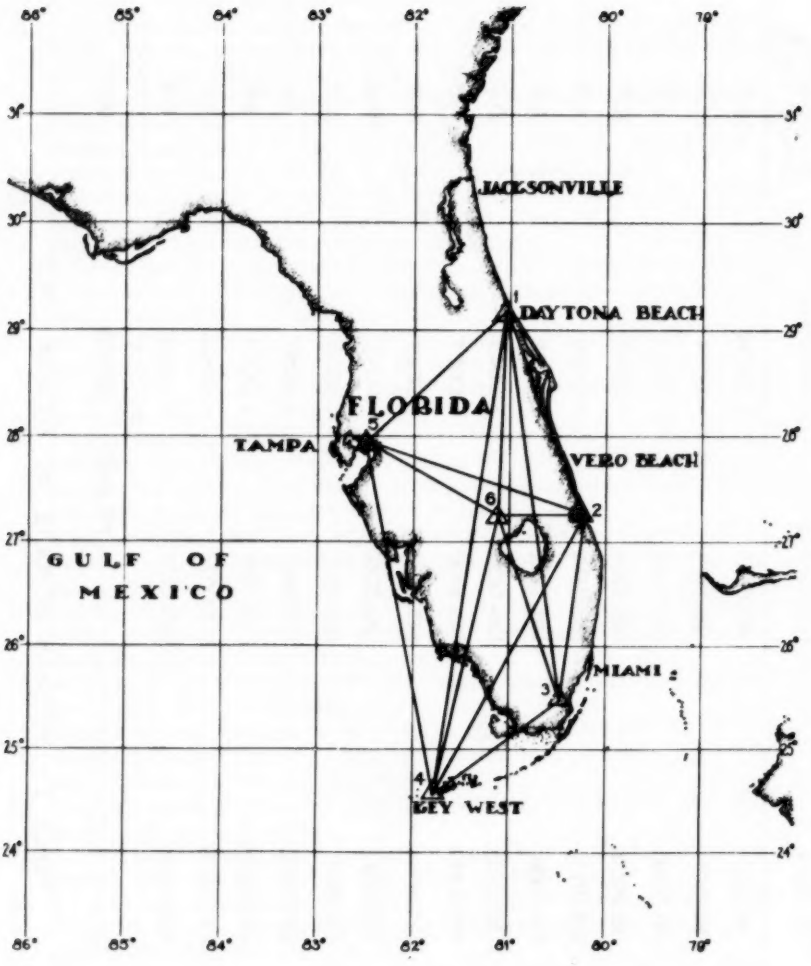
JACKSONVILLE
DAYTONA BEACH
FLORIDA
TAMPA
VERO BEACH
GULF OF MEXICO
MIAMI
KEY WEST
1
2
3
4
5
6

FIGURE 1

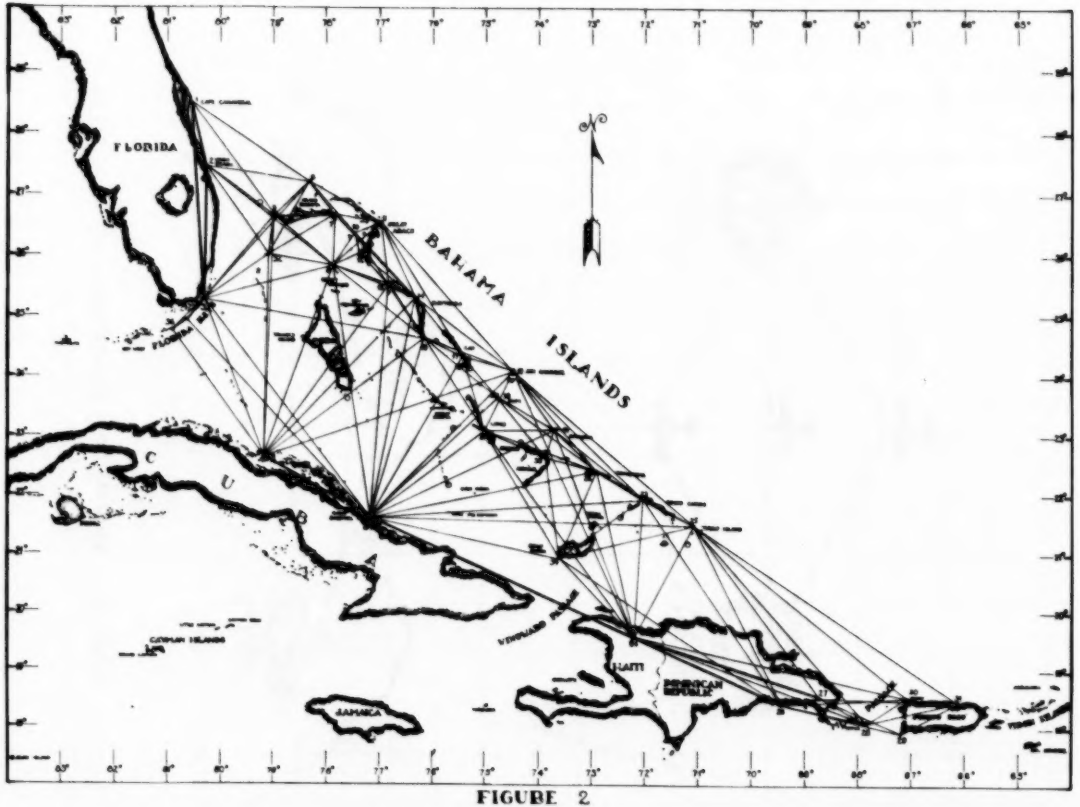

FIGURE 2

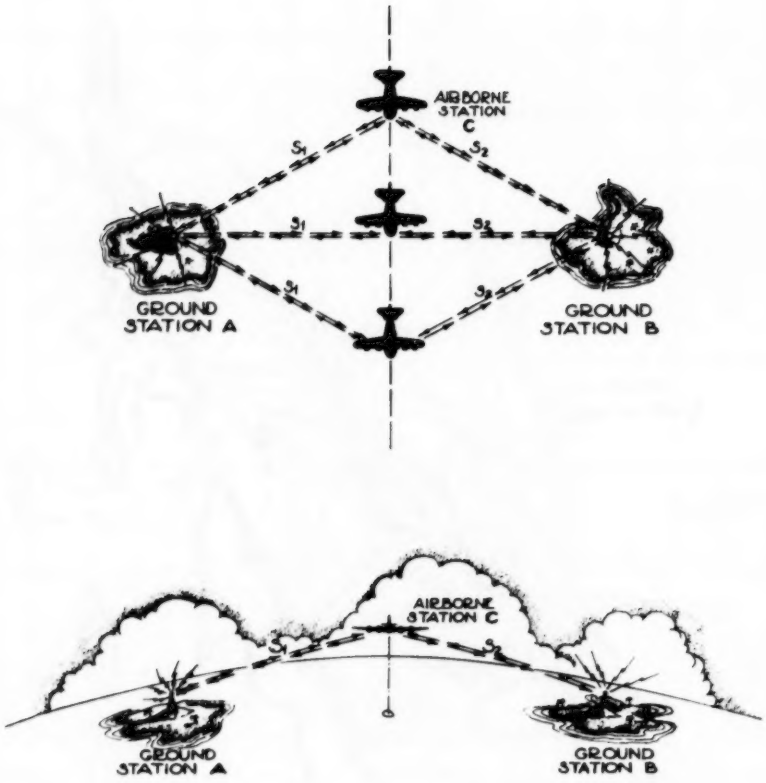

FIGURE 3 SHORAN LINE CROSSING.

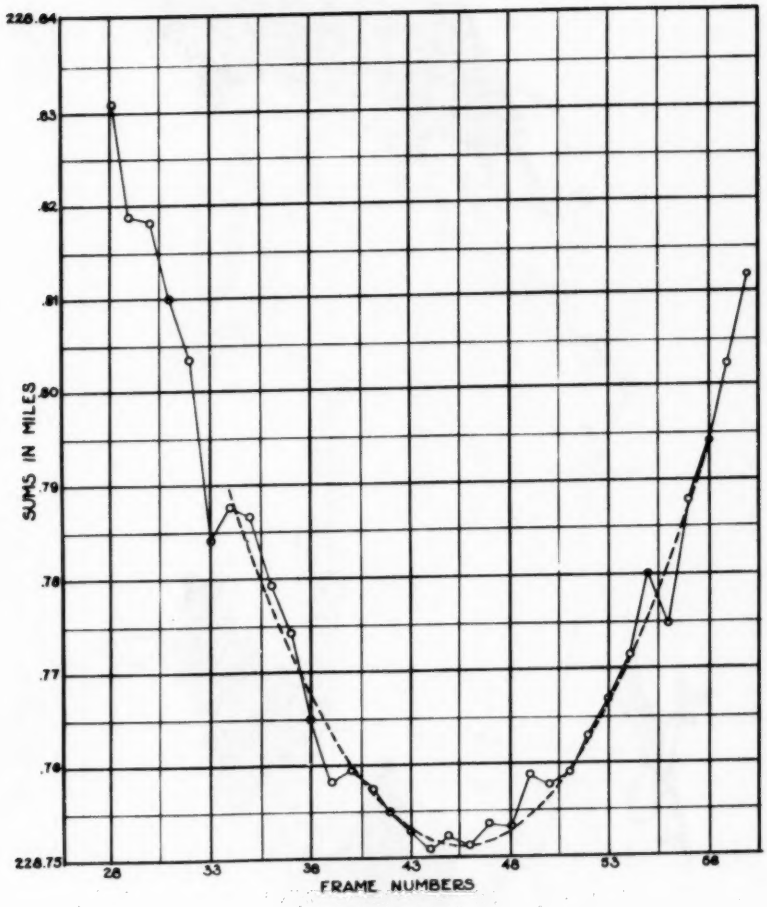

FIGURE 4. GRAPHICAL PLOT OF OBSERVED SUM DISTANCE VS FRAME NUMBER AND THE CORRESPONDING FITTED PARABOLA.

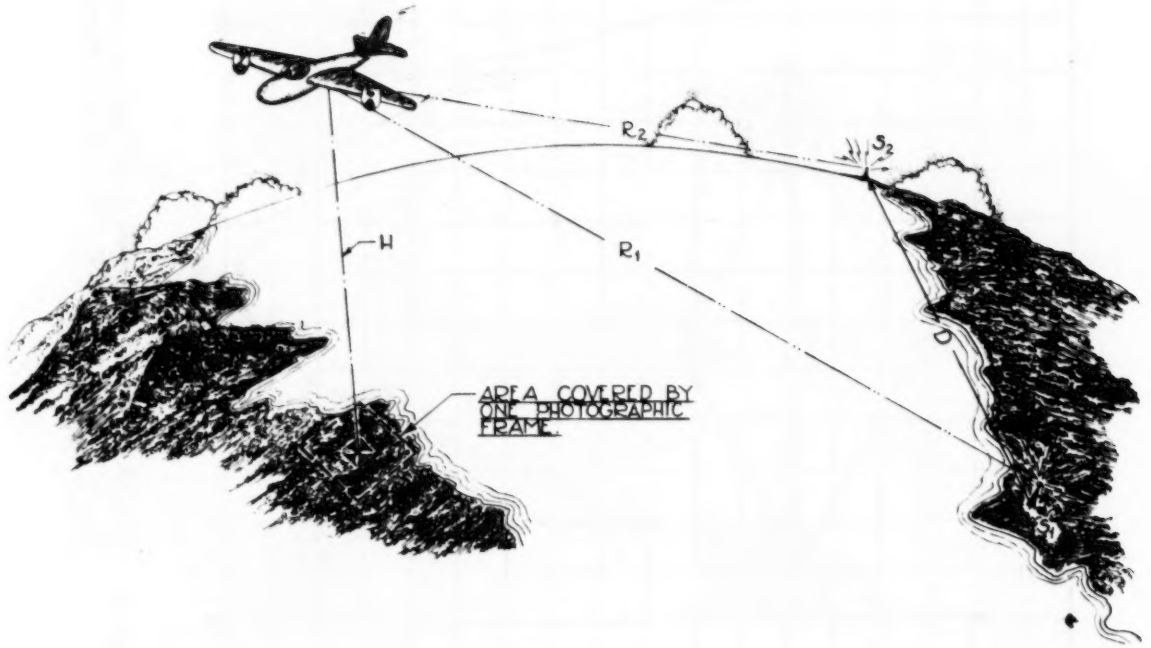

FIGURE 5
SHORAN CONTROL PHOTOGRAPHY

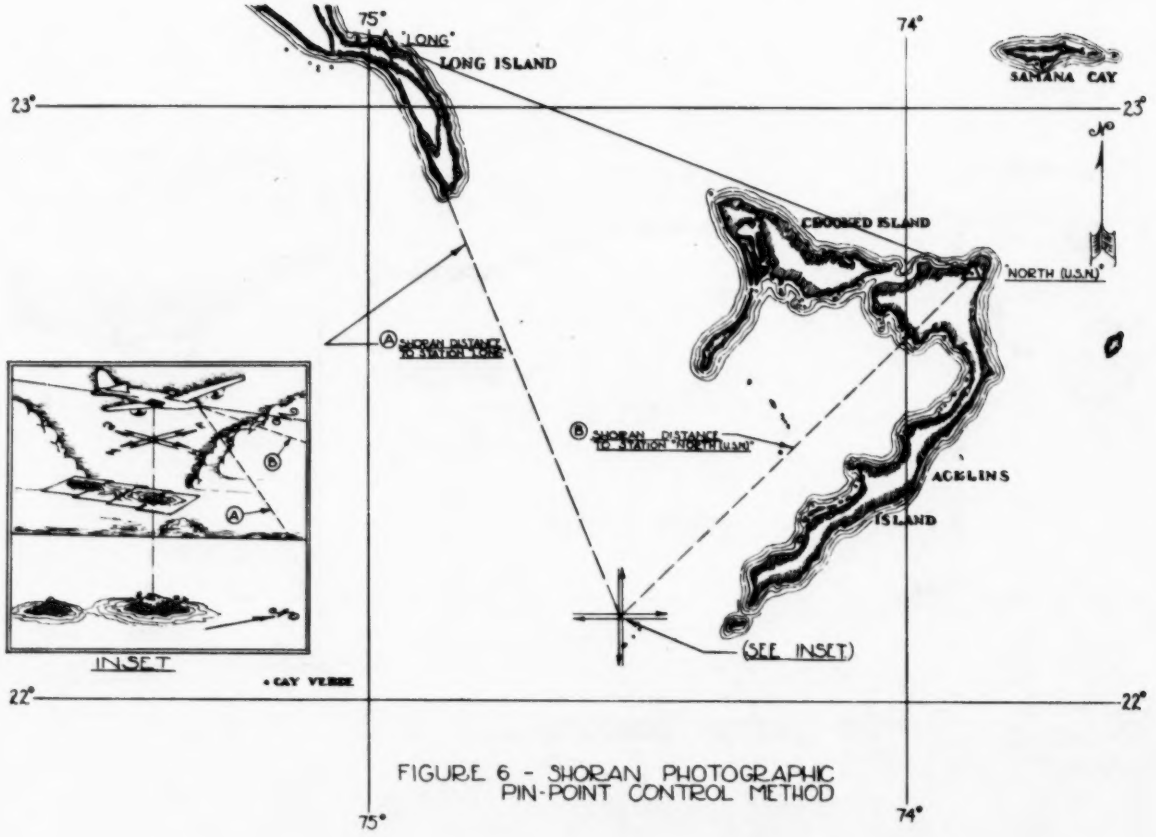

FIGURE 6 - SHORAN PHOTOGRAPHIC PIN-POINT CONTROL METHOD

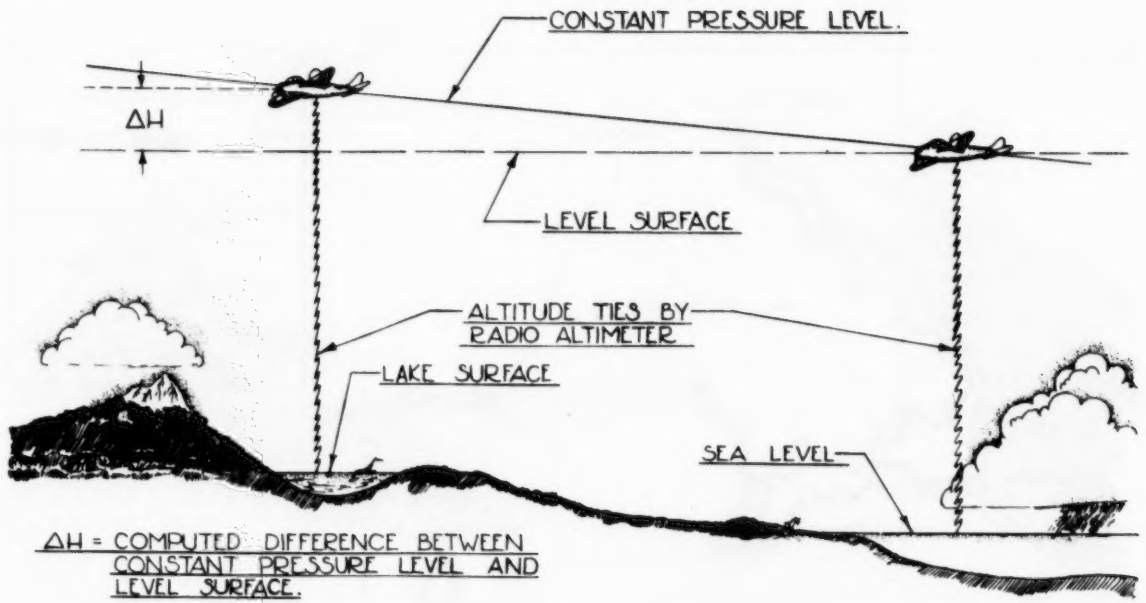
CONSTANT PRESSURE LEVEL.
ΔH
LEVEL SURFACE
ALTITUDE TIES BY RADIO ALTIMETER
LAKE SURFACE
SEA LEVEL
ΔH = COMPUTED DIFFERENCE BETWEEN CONSTANT PRESSURE LEVEL AND LEVEL SURFACE.

FIGURE 7